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1 Introduction

The aim of this study is to develop a comprehensive Computational Fluid Dynamics (CFD) based model for predicting the permeability coefficient of porous media as exfoliated vermiculite. Vermiculite is a mica-type mineral, which is used as a substitute for asbestos for gasket application. A finite element based method is presented for evaluating the effective permeability of such porous solids. The main micro geometry characteristics are determined using scanning electron microscopy observations of vermiculite. Then, the 3-D micro-scale geometries of the porous solids are defined with the ANSYS software. The relation between the microstructure of the porous media and the effective permeability is established. Results of numerical simulations are finally compared with experimental permeability on vermiculite gaskets.

2 Micro geometry definition

The estimation of the permeability [1-2] of a porous medium always remains a very difficult task because it is necessary to take into account lot of geometric parameters, as the porosity, the tortuosity, the specific surface… A representation of the 3-D micro-morphologies is essential to evaluate the effect of specific parameters for the optimization of permeability [3]. The direct pore-level numerical simulation of the fluid flow governing equations has became feasible with the advent of high performance of computer and the ability to obtain good geometrical representations of the porous matrix (electronic scan microscopy, tomography). In order to evaluate the main parameters of micro geometry of studied exfoliated vermiculite samples, some electronic microscopy scans were performed. The electronic scan microscopy (SEM) gives some information on the structure of porous media, but it does not generally provide direct three-dimensional information. However, the SEM images (Fig. 1) of a sample of vermiculite shows that the layers of vermiculite are shaped like small platelets stacked according an average axis.

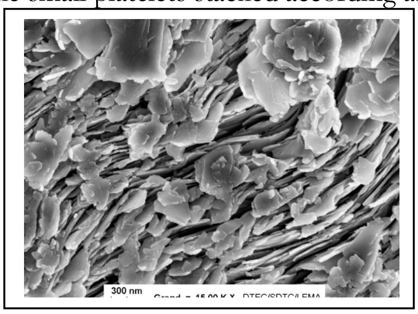

Figure 1 – image SEM of a sample of the vermiculite

In order to evaluate the pore network, several SEM observations are performed. The pore network results from the lack of some platelets in this stacking.Informative geometric parameters are needed to describe the complex spatial arrangement of pore. For the present study, spatial distributions and dimensions of pores are partly determined with an Image Processing Software and with direct image analysis of SEM images.

3 Numerical Model

The proposed method has several distinctive features. First, the 3D micro structures of the porous media are constructed with a parametric program which allow to control the pore sizes, pore orientations, interconnections… Using the FEM software ANSYS and the geometric parameters previously determined, a program generates a pore network with a micro geometry as similar as possible with studied material. Figure 2 illustrated and example of the pore network. The porosities without connection with the pore network are deleted before calculation.

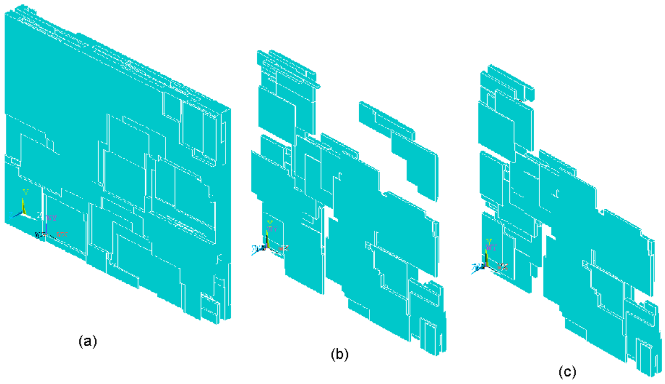

Figure 2 – Construction of the 3D model: (a) solid part of the REV (b) network of the pores (c) the connected pores

Because of the field of sealing application of such vermiculite, the following assumptions are made: the flow is laminar, permanent and isotherm, the volume forces and inertia effects are neglected and the solid matrix is incompressible. The pore network is mesh with 3D Fluid-Thermal tetrahedral element. An optimum mesh size, which produces an accurate solution with a reasonable time, was determined with a preliminary mesh sensitive study. In order to simulate the effective behavior of the macroscopic, adequate boundary conditions are applied on the Representative Volume Element (periodic boundary, pressure gap and no slip boundary condition). Finally, the ANSYS CFD code is used to solve the 3D incompressible continuity and Navier–Stokes equations in the pore-space.

4 Results and discussion

The CFD results provide an effective permeability for a porous media with a specific porosity network. Two examples of macroscopic permeability are displayed in Table 1. The first results highlight that the permeability depends strongly of the micro geometry of the porous network. For the same pore volume ratio, the permeability could be very different. Furthermore, this permeability is strongly anisotropic for vermiculite with a pore network build up with pores like a platelet oriented around to an average axis. It can be notice that the effective permeability is of the same order of magnitude with the first experimental results on vermiculite.

Sample	Pore volume ratio	Permeability Model (m^2)
Sample 1	21,8%	2,31.10-17
Sample 2	32,6%	1,88.10-16

Table 1 – experimental and numeric permeability

5 Conclusion

In this paper, a FEM based model with the study of SEM images is proposed in order to evaluate the macroscopic permeability of a porous media as the vermiculite. As main benefit, such model could estimate the permeability of a porous media according to the micro geometry. One of the perspectives, is to obtain a more precise description of the porosity network by using systematically efficient Image Processing Software on numerous SEM scan in order to have average information in three directions of the pore network.

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